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APRIL 1990

Ontario

Environment
Environnement

Jim Bradley Minister/ministre

ISBN 0-7729-6762-8

PREDICTION OF ANNUAL NITROGEN AND PHOSPHORUS EXPORT FROM FORESTED STREAM CATCHMENTS IN CENTRAL ONTARIO

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APRIL 1990

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ABSTRACT

A need to predict nutrient export from unmonitored forested stream catchments in Ontario has been identified as part of a program to estimate the impact of shoreline development on lake trophic status. This paper presents empirical regression models for prediction of annual NH_4^+, NO_3^- total organic N and total P export from forested stream catchments in the Precambrian shield as functions of geology, physiography, hydrology and limited annual meteorological data. The data were collected from 32 streams in the Muskoka-Haliburton area of central Ontario measured during the 8 year period 1976/77 to 1983/84. A minimum of 6 consecutive years of sampling was necessary to avoid the possibility of a low R^2.

RÉSUMÉ

On a identifié la nécessité de prédire l'exportation de substances nutritives en provenance des bassins boisés des cours d'eau non contrôlés en Ontario dans le cadre d'un projet visant à estimer l'effet des développements riverains sur l'état trophique des lacs. Ce rapport présente des modèles de régression empiriques pour aider à prédire le mouvement annuel de NH_4^+, de NO_3^-, du N total organique et du P total en provenance de bassins boisés des cours d'eau dans le Bouclier précambrien, en fonction de la géologie, de la physiographie, de l'hydrologie et des données météorologiques annuelles restreintes. Les données ont été recueillies dans 32 cours d'eau dans la région de Muskoka-Haliburton du centre de l'Ontario durant une période de 8 ans allant de 1976/77 à 1983/84. Un échantillonnage au cours d'une période minimale de 6 années consécutives était nécessaire pour éviter la possibilité d'un R^2 faible.

INTRODUCTION

A concerted effort has been made during the past two decades to predict the trophic status of lakes based on the response of lakes to total phosphorus (TP) loading and concentration (Dillon and Rigler 1975). Development of predictive tools has centred upon steady state models because parameterization of steady state models is limited and because they are readily adaptable as management tools.

Two noteworthy models that have met with some success are those that predict chlorophyll a as a function of TP concentration in P-limited lakes (Dillon and Rigler 1975a; Jones and Bachmann 1976; Canfield 1983; Prepas and Trew 1983; Riley and Prepas 1985; Dillon et al. 1988) and those that predict TP concentration as a function of annual TP load and flushing characteristics (Vollenweider 1969; Dillon and Rigler 1974b; Dillon 1975; Kirchner and Dillon 1975; Larsen and Mercier 1976; Canfield and Bachmann 1981; Frisk et al. 1981; Chapra and Reckhow 1983; Reckhow and Chapra 1983). Together, these models permit dose/response estimates by linking land use activities in the catchment to changes in water quality.

Effort has also been expended towards predicting annual nutrient loads from a range of land use types. These efforts have been primarily analyses relating export to land use categories such as forest, pasture, urban, row crop, etc. (Neilson and Mackenzie 1977; Hill 1978, 1981; Kauppi 1979; Beaulac and Reckhow 1982; Cootes et al. 1982; Daniel et al. 1982; Clesceri et al. 1986a, 1986b; Harper and Stewart 1987). However, models of export from single land use categories are, in general, lacking although the effects of drainage

density and bedrock geology were presented by Kirchner (1975) and Dillon and Kirchner (1975).

In the Muskoka-Haliburton region of central Ontario, a need to predict nutrient export from unmonitored forested stream catchments has been identified as part of a program to estimate the impact of shoreline development on lake trophic status. This paper presents empirical regression models for prediction of annual NH_4^+, NO_3^-, total organic nitrogen (TON) and TP export from forested stream catchments as functions of bedrock geology, surficial geology, physiography, hydrology and limited annual meteorological data. No attempts were made to include soil chemistry or stream chemistry data other than N and TP export. The data were collected from 32 streams in central Ontario measured during the 8 year period 1976/77 to 1983/84 as part of the Ontario Government's Lakeshore Capacity Study.

MATERIALS AND METHODS

Study Sites

Thirty-two streams in the central Ontario district of Haliburton-Muskoka were sampled approximately one to four times per month from 1976/77 to 1983/84. The catchments are underlain by Precambrian metamorphic silicate bedrock and were primarily forested with varying degrees of cottage development and no upstream lakes. Minor till plains (continuous moraine deposits > 1 m thick) and thin till deposits (< 1 m thick) interrupted

by rock ridges are the dominant surficial geological groups. Detailed descriptions of the geology and physiography of the catchments can be found in Jeffries and Snyder (1983), LaZerte and Dillon (1984), Girard et al.(1985), Seip et al. (1985), Dillon et al. (1987) and Reid et al. (1987).

Analytical Methods

Sample collection techniques are described in detail in Locke and Scott (1986), while analytical methods for TP, NO_3^-, NH_4^+ and TKN are outlined in Ontario Ministry of the Environment (1983). TON was defined as TKN - NH_4^+. Units are ug-at/m^2/yr. Of the 256 stream-years of data, 206 had a complete set of observations.

Parameter definitions and codes (in capital block letters) are listed below.

Meteorology and hydrology: mean annual air temperature (TEMP, °C), relative humidity (HUMID, %), annual stream baseflow (BASEFLOW; defined as the minimum observed flow rate extrapolated to an annual value, m yr^{-1}), annual stream discharge (RUNOFF, m yr^{-1}), annual stream quickflow (QUICKFLOW; defined as runoff-baseflow, m yr^{-1}) and precipitation (PRECIP, m yr^{-1}), ratio of annual maximum to minimum stream discharge rate (MAXM), proportion of total annual runoff occurring February 1 - May 31 (SPRINGFLOW) and ratio of runoff to precipitation (YIELD).

Physiography: catchment area (AREA, m^2), average catchment grade (GRADE, %), stream length (STRML, m), ratio of area to stream length (ASTRML, m) and road length (ROAD, m).

Bedrock geology: % area as biotite, horneblende and gneiss (BHG), diorite (DIOR), amphibolite and schist (AS), migmatite (MIG), marble (MARB) and gneiss, meta arkose and marble (GMAM),

Surficial geology: % area as pond (POND), exposed rock (ROCK), esker (ESKER), outwash (WASH), drumlin (DRUMLIN), peat (PEAT), sand (SAND), carbonate till (TLLCRB), minor till plain (MTLLPL) and thin till with exposed rock ridges (TTLLRR).

Statistical Analyses

Pearson correlation and stepwise (forward) multiple linear regression analyses were performed with SAS using each stream-year as an observation (n = 256; referred to as data set A) and then using the average for each stream over the 8 year period (n=32; referred to as data set B).

The objective of the N and TP regressions was to derive empirical equations in which mean annual nutrient export predictions were independent of each other, i.e. it was hoped that regressions without N or TP as independent variables would have acceptable R^2, arbitrarily defined as > 0.7. To accomplish this, multiple linear regressions were first derived with untransformed variables, with and without nutrients as independent variables, and then

compared to regressions with an expanded list of both untransformed variables and their reciprocals (for variables which never 0) and squares. Other types of mathematical transformations of variables were not investigated.

RESULTS

Geological and physiographical characteristics for the 32 study catchments are listed in Table 1 and means and standard deviations from 1976/77-1983/84 for the chemical, hydrological and meteorological parameters are listed in Table 2. Mean catchment export ranged from 66 to 1,129 ug-at P m^{-2} yr^{-1} and 8,746 to 67,844 ug-at N m^{-2} yr^{-1}.

TN/TP mean annual export ratios (molar) ranged from 24 to 389 with a mean ± 1 standard deviation of 108 ± 82. All TN/TP export ratios were greater than 43 except DE5 and DE6 which were both 24.

(1) Correlation Analysis

TP export was best correlated with the % area covered with peat and % migmatite bedrock using 256 stream-years (data set A; Table 3) and the average annual data (data set B; Table 4).

The highest NO_3^- correlation in data set A was only 0.39 (with grade). Correlations increased when annual average data were used with two correlations > 0.40 (with grade and with % area as mtllpl).

NH_4^+ in data set A was best correlated with TP ($r = 0.45$). This increased slightly to 0.47 in data set B. Two other correlations with NH_4^+ also emerged in the long-term data set - springflow proportion and % pond.

TON in data set A was best correlated with runoff, yield, quickflow and TP ($r > 0.4$). In data set B, the correlations decreased. Two other correlations which were > 0.3 in data set A (with % area as peat and mtllpl) did not change with long-term averaging.

In general, correlations with TP, NH_4^+ and NO_3^- export increased and correlations with TON export decreased when 8-year annual means were used. The number of parameters with correlations greater than 0.30 with at least one of the nutrient export parameters also increased.

Visual inspections of bivariate scatter diagrams did not reveal non-linear relationships.

(2) Regression Analysis

Stepwise regression analyses were performed with data sets A and B to predict nutrient export using untransformed variables. Regressions were performed with and without N fractions and TP as independent variables (Tables 5 and 6). The following summarizes the regression analyses:

1) TP prediction required NH_4^+ as an independent variable to achieve adequate fit ($R^2 > 0.7$) in data sets A and B.

2) In data set A, R^2 for NO_3^-, NH_4^+ and TON regressions were less than 0.7. Including TP as an independent variable increased the R^2 for NH_4^+ from 0.45 to 0.65. NO_3^- was insensitive to inclusion of NH_4^+, TON and TP as independent regression variables with R^2 remaining at 0.43.

3) R^2 increased for NO_3^-, TP and most of the NH_4^+ regressions when 8-year annual averages rather than individual stream-years were used. However, R^2 for TON decreased to 0.30.

4) The first variable accepted by the stepwise procedure did not change when data were averaged for the 8 year period. The secondary independent variables accepted frequently changed when data were averaged over the 8 year period.

5) Assuming that a minimum R^2 of 0.70 is acceptable, only annual TP export with NH_4^+ as an independent variable can be predicted from short-term data.

6) TP (with NH_4^+) and NO_3^- (with TON) can be accurately predicted from long-term data. Neither TON nor NH_4^+ can be accurately predicted from short-term or long-term data.

It appears from a regression analysis of untransformed variables that NH_4^+ and TP are co-dependent (i.e., NH_4^+ is an independent variable in the TP regression and TP is an independent variable in the NH_4^+ regression). Only TP can be predicted from short-term or long-term data and only NO_3^- and TP can be predicted from long-term data with confidence ($R^2 > 0.70$).

7) When PC1 was excluded from the long-term data set B, R^2 for all TON regressions increased greatly (Tables 6 and 7). It appears, therefore, that PC1 is an anomaly with respect to TON export. NO_3^- regressions were insensitive to TON, NH_4^+ and TP and the R^2 for NO_3^- increased to 0.73. The R^2 for NH_4^+ increased to 0.72 but still required TP as an independent variable.

The correlation coefficients between TON and TP, NO_3^-, NH_4^+, maxm, peat, mtllpl, grade, bhg and mig increased when PC1 was excluded (Table 8). PC1 was not an outlier in a principal components analysis using data set B, suggesting that the PC1 anomaly was restricted to the very high TON export and was therefore masked in the analysis. The PC1 mean annual TON export of 49.1 mg-at m^{-2} yr^{-1} was outside the mean ± 1 standard

deviation of 14.3 ± 7.4 mg-at m^{-2} yr^{-1} for the 32 catchments. Mean TON export excluding PC1 ranged from 5.8 to 22.2 mg-at m^{-2} yr^{-1} and the mean ± 1 standard deviation was 13.2 ± 4.0 mg-at m^{-2} yr^{-1}.

Transformed variables (reciprocals and squares) were added to the independent variable list to see whether R^2 increased in stepwise regressions (Table 9).

8) Transformations increased regression R^2 for long-term NH_4^+ and TP regressions; in fact, transformation of independent variables eliminated the need for NH_4^+ as an independent variable in the TP regression. The TON and NO_3^- R^2 values, on the other hand, changed only slightly.

The bedrock geology parameters were removed as independent variables from the regression analyses of average, long-term export (Tables 10-13), primarily because these parameters did not appear generally important except for diorite in the NH_4^+ regression and marble in the NH_4^+ regression. Hence, their removal might simplify data requirements. Removal of bedrock geology resulted in the R^2 for long-term NO_3^- export (with untransformed variables only) increasing from 0.73 to 0.81. The R^2 for long-term NH_4^+ export (including transformed variables) decreased from 0.92 to 0.81. However, in the latter case, the NH_4^+ regression without bedrock geology was more satisfying because streamlength, which appeared four times in various guises, was no longer significant.

Recommended regression equations for long-term, mean annual nutrient export are listed in Tables 10 - 13. Bedrock geology and PC1 were excluded from the data set.

The length of the sampling period on R^2 values was examined using the independent variables for TP export recommended in Table 10. Sampling periods ranged from 1 to 8 consecutive years. Within each sampling period of n years length, there were 9 - n data subsets. As the number of consecutive years of sampling increased from 1 to 8, the minimum R^2 gradually increased from 0.51 to 0.85 (Table 14). The minimum number of consecutive sampling years necessary to avoid the possibility of a low R^2 was at least 5, preferably 6 years.

Of course, models selected from application of stepwise regession to 8 year and shorter averages will likely differ. Stepwise regressions for TP export were therefore performed on the different data subsets of four and six consecutive sampling years (Table 15). The independent variable list included all untransformed and transformed variables except N species. The stepwise procedure sometimes selected regressions which yielded smaller R^2 values than the regressions using the seven variables selected from 8 year averages.

DISCUSSION

The primary objective of the empirical model development presented here was to permit prediction of long-term, mean annual nutrient export from forested catchments in the Precambrian shield area of central Ontario with a minimum of labour-intensive field and laboratory work. The regressions are functions of independent variables which can be readily obtained from surficial geology and topological maps. The hydrological data can

be obtained in the field or from a hydrological model such as the Birkenes model (Hooper et al. 1988).

The use of transformed independent variables was strictly empirical and had no a priori theoretical rationale based on hypotheses of cause and effect. Transformations resulted in a TP regression that had a much higher R^2 and was independent of N export. Similarly, transformations resulted in a much higher R^2 for NH_4^+, although the dependence on TP could not be eliminated. It is questionable whether the transformed variables are causally related to nutrient export, nevertheless, their inclusion is operationally justified.

Several points are evident from this study.

1) Correlations and regression R^2 values were typically higher for the averaged data (B) although some exceptions were noted for correlations with TON. The minimum sampling period required to avoid the possibility of a low R^2 for TP export is at least 5 consecutive years, although 6 is preferable.

2) TON export from PC1 was anomalously high, possibly because of the extent of acidification (Dillon et al. 1987; Dillon and Molot 1989; Molot et al. 1989). The regression models recommended in Tables 10-13 should not be applied to acidified catchments, particularly for TON.

3) The type of bedrock geology is not a very important factor in regression models of nutrient export from forested stream catchments in the Precambrian shield area of central Ontario.

4) The relative areal extent of peat is an important factor in regression models of TP, NH_4^+ and TON export.

5) The importance of grade in the regression model of NO_3^- export is consistent with the hypothesis that NO_3^- is a mobile anion readily affected by leaching (Szperlinski and Badowska 1977a, 1977b; Johnson and Cole 1980; Dillon and Molot 1989). Most of the NO_3^- is exported during spring melt (Molot et al. 1989).

Kirchner (1975) found a significant correlation of 0.94 between drainage density and TP export from catchments in the Precambrian shield with the highest export value being 274 μg-at m^{-2} yr^{-1}. In our data set, including PC1, the correlation was 0.03 (n=32). For catchments with long-term mean export < 300 μg-at m^{-2} yr^{-1}, the correlation was 0.54. Hence, we conclude that drainage density is important only at very low TP export.

REFERENCES

Beaulac, M.N. and K.H. Reckhow. 1982. An examination of land-use nutrient export relationships. Water Res. Bull. 18: 1013-1024.

Canfield, D.E., Jr. 1983. Prediction of chlorophyll a concentrations in Florida lakes: the importance of phosphorus and nitrogen. Water Resour. Bull. 19: 255-262.

Canfield, D.E., Jr. and R.W. Bachmann. 1981. Prediction of total phosphorus concentrations, chlorophyll a, and Secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. Bd. 38: 414-423.

Chapra, S.C. and K.H. Reckhow. 1983. Engineering approaches for lake management. Volume 2, Butterworth Publishers, Toronto, 492 p.

Cootes, D.R., E.M. MacDonald, W.T. Dickinson, R.C. Ostry and R. Frank. 1982. Agriculture and water quality in the Canadian Great Lakes Basin: I. Representative agricultural watersheds. J. Environ. Qual. 11: 473-481.

Clesceri, N.L., S.J. Curran and R.I. Sedlak. 1986a. Nutrient loads to Wisconsin Lakes: Part I. Nitrogen and phosphorus export coefficients. Water Resour. Bull. 22: 983-990.

Clesceri, N.L., S.J. Curran and R.I. Sedlak. 1986b. Nutrient loads to Wisconsin Lakes: Part II. Relative importance of nutrient sources. Water Resour. Bull. 22: 991-1000.

Daniel, T.C., R.C. Wendt, P.E. McGuire and D. Stoffel. 1982. Nonpoint source loading rates from selected land uses. Water Resour. Bull. 18: 117-120.

Dillon, P.J. 1975. The phophorus budget of Cameron Lake, Ontario: the importance of flushing rate to the degree of eutrophy of lakes. Limnol. Oceanogr. 20: 28-39.

Dillon, P.J. and W.B. Kirchner. 1975. The effects of geology and land use on the export of phosphorus from watersheds. Water Res. 9: 135-148.

Dillon, P.J. and F.H. Rigler. 1974a. The phosphorus-chlorophyll relationship in lakes. Limnol. Oceanogr. 19: 767-773.

Dillon, P.J. and F.H. Rigler. 1974b. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31: 1771-1778.

Dillon, P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Can. 32: 1519-1531.

Dillon, P.J., R.A. Reid and E. de Grosbois. 1987. The rate of acidification of aquatic ecosystems in Ontario, Canada. Nature 329: 45-48.

Dillon, P.J., M. Lusis, R. Reid and D. Yap. 1988. Ten-year trends in sulphate, nitrate and hydrogen deposition in central Ontario. Atmos. Environ. 22: 901-905.

Dillon, P.J. and L.A. Molot. 1989. Retention of ammonium and nitrate in lakes and forested catchments. In prep.

Frisk, T., J.S. Niemi and K.A.I. Kinnunen. 1981. Comparison of statistical phosphorus-retention models. Ecol. Model. 12: 11-27.

Harper, D.M. and W.D.P. Stewart. 1987. The effects of land use upon water chemistry, particularly nutrient enrichment, in shallow lowland lakes: comparative studies of three lochs in Scotland. Hydrobiol. 148: 211-229.

Hill, A.R. 1978. Factors affecting the export of nitrate-nitrogen from drainage basins in southern Ontario. Water Res. 12: 1045-1057.

Hill, A.R. 1981. Stream phosphorus exports from watersheds with contrasting land uses in southern Ontario. Water Resour. Bull. 17: 627-634.

Hooper, R.P., A. Stone, N. Christophersen, E. de Grosbois and H.M. Seip. 1988. Asessing the Birkenes model of stream acidification using a multisignal calibration methodology. Water Resour. Res. 24: 1308-1316.

Johnson, D.W. and D.W. Cole. 1980. Anion mobility in soils: relevance to nutrient transport from forest ecosystems. Environ. Int. 3: 79-90.

Jones, J.R. and R.W. Bachmann. 1976. Prediction of phosphorus and chlorophyll levels in lakes. J. Water Poll. Control Fed. 48: 2176-2182.

Larsen, D.P. and H.T. Mercier. 1976. Phosphorus retention capacity of lakes. J. Fish. Res. Bd. Can. 33: 1742-1750.

Kauppi, L. 1979. Effects of land use on the diffuse load of phosphorus and nitrogen. Nordic Hydrol. 79-88.

Kirchner, W.B. 1975. An examination of the relationship between drainage basin morphology and the export of phosphorus. Limnol. Oceanogr. 20: 267-270.

Kirchner, W.B. and P.J. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Resour. Res. 11: 182-183.

Molot, L.A., P.J. Dillon and B. LaZerte. Factors affecting alkalinity concentrations of streamwater during snowmelt in central Ontario. Can. J. Fish. Aquat. Sci. 46: 1658-1666.

Neilsen, G.H. and A.F. Mackenzie. 1977. Relationships between soluble and sediment nutrient losses, land use and types of soil in agricultural watersheds. Proc. 12th Can. Symp., Water Poll. Res. Can., pp. 121-134.

Ontario Ministry of the Environment. 1983. Handbook of analytical methods for environmental samples, Vols. 1 and 2. Toronto, Ontario, Canada.

Prepas, E.E. and D.O. Trew. 1983. Evaluation of the phosphorus-chlorophyll relationship for lakes off the Precambrian Shield in western Canada. Can. J. Fish. Aquat. Sci. 40: 27-35.

Reckhow, K.H. and S.C. Chapra. 1983. Engineering approaches for lake management. Volume 1, Butterworth Publishers, Toronto, 340 p.

Riley, E.T. and E.E. Prepas. 1985. Comparison of the phosphorus-chlorophyll relationships in mixed and stratified lakes. Can. J. Fish. Aquat. Sci. 42: 831-835.

Szperlinski, Z. and K. Badowska. 1977a. Significance of sorption properties of soils in predicting the migration of nitrogen compounds into natural waters. Ekol. Polska 25: 675-688.

Szperlinski, Z. and K. Badowska. 1977b. The effect of intense fertilization on migration of nitrogen compounds in soil. Ekol. Polska 25: 689-702.

Vollenweider, R.A. 1969. Moglichkeiten und grenzen elementarer modelle der stoffbilanz von seen. Arch. Hydrobiol. 66: 1-36.

Table 1. Geological and physiographical characteristics of the 32 study catchments in central Ontario. Abbreviations are defined in the text. Units are % except for Area (m^2) and Road, Streamlength and Stream Density (m).

STRM	AREA	GRADE	ROAD	STRML	ASTRML	BHG	DIOR	AS	MIG	MARB	GMAM	TLLCRB	MTLLPL	TTLLRR	PEAT	ROCK	WASH	ESKER	DRUM	SAND	POND
BC1	204300	7.0	15400	487.60	418.92	100.0	0.0	0.0	0.0	0.0	0.0	0.0	94.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BE1	5716000	1.0	4300	3688.08	1549.86	0.0	0.0	0.0	0.0	20.6	79.4	89.3	0.0	0.0	6.9	0.0	0.0	1.5	0.1	0.0	2.2
CB1	596900	3.0	0	1066.80	559.52	100.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2	72.4	2.8	0.6	0.0	0.0	0.0	0.0	0.0
CB2	1260000	2.0	0	1828.80	688.98	100.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	75.3	8.0	0.0	0.0	0.0	0.0	0.0	0.0
CN1	4563000	1.2	0	2260.00	2019.03	0.0	0.0	0.0	100.0	0.0	0.0	0.0	17.1	67.1	8.6	0.0	0.0	0.0	0.0	0.0	7.2
DE10	788900	1.0	1300	975.36	808.83	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	82.9	17.1	0.0	0.0	0.0	0.0	0.0	0.0
DE11	762700	1.0	0	1981.20	384.97	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	79.1	20.9	0.0	0.0	0.0	0.0	0.0	0.0
DE5	299800	1.0	10100	762.00	393.44	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	74.6	25.4	0.0	0.0	0.0	0.0	0.0	0.0
DE6	218000	1.6	15600	487.68	447.01	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	78.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
DE8	669600	1.0	28000	1219.20	549.21	0.0	0.0	0.0	100.0	0.0	0.0	0.0	13.7	78.1	8.2	0.0	0.0	0.0	0.0	0.0	0.0
DK1	473000	1.4	31800	1645.92	287.38	0.0	0.0	0.0	0.0	11.9	88.1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HAL12	4379000	2.6	7100	4175.76	1048.67	5.9	0.0	0.0	0.0	94.1	0.0	97.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
HO1	656000	9.0	0	914.40	717.41	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
HP3	259900	4.0	19600	1005.84	258.39	93.0	0.0	7.0	0.0	0.0	0.0	0.0	79.5	11.2	9.3	0.0	0.0	0.0	0.0	0.0	0.0
HP3A	196500	8.0	8500	762.00	257.87	42.6	0.0	57.4	0.0	0.0	0.0	0.0	97.1	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
HP4	1195300	5.0	3700	2042.16	585.31	13.2	0.0	86.8	0.0	0.0	0.0	0.0	56.1	32.8	0.0	0.9	0.0	0.0	0.0	7.5	2.7
HP5	1905300	3.0	0	1828.80	1041.83	100.0	0.0	0.0	0.0	0.0	0.0	0.0	34.5	48.6	13.3	0.0	0.0	0.0	0.0	3.6	0.0
HP6	99700	8.0	11100	701.04	142.22	100.0	0.0	0.0	0.0	0.0	0.0	0.0	45.2	54.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HP6A	152800	10.0	0	609.60	250.66	33.3	66.7	0.0	0.0	0.0	0.0	0.0	6.6	84.9	8.5	0.0	0.0	0.0	0.0	0.0	0.0
JY1	73000	8.0	0	457.20	159.67	100.0	0.0	0.0	0.0	0.0	0.0	0.0	77.4	22.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JY3	6663000	2.5	0	3048.00	2186.02	100.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	78.4	5.2	0.1	0.0	0.0	0.0	2.5	0.4
JY4	410000	9.0	0	762.00	538.06	100.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	83.5	0.0	0.0	0.0	0.0	0.0	2.8	0.0
ME1	4379000	2.6	7100	4175.76	1048.67	5.9	0.0	0.0	0.0	94.1	0.0	97.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
PC1	233400	5.9	0	790.00	295.44	99.36	0.0	0.0	0.64	0.0	0.0	0.0	9.6	80.2	7.0	3.2	0.0	0.0	0.0	0.0	0.0
PT1	213000	8.8	0	1127.76	188.87	100.0	0.0	0.0	0.0	0.0	0.0	0.0	51.7	38.0	0.0	0.0	5.6	0.0	0.0	0.0	4.7
RC1	1335800	1.0	3000	2895.60	461.32	100.0	0.0	0.0	0.0	0.0	0.0	0.0	53.2	41.1	0.0	0.0	0.8	0.0	0.0	0.0	4.9
RC2	269600	1.5	1400	731.52	368.55	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.9	10.5	19.4	0.0	0.0	0.0	0.0	2.2
RC3	704900	3.5	0	1280.16	550.63	100.0	0.0	0.0	0.0	0.0	0.0	0.0	81.7	2.7	9.9	1.2	0.0	0.0	0.0	0.0	4.5
RC4	454600	2.5	0	1005.84	451.96	100.0	0.0	0.0	0.0	0.0	0.0	0.0	76.3	16.0	2.9	0.0	0.0	0.0	0.0	0.0	4.8
TBAY1	79000	24.0	0	381.00	207.35	100.0	0.0	0.0	0.0	0.0	0.0	0.0	56.1	35.5	8.4	0.0	0.0	0.0	0.0	0.0	0.0
TWN1	4267000	1.8	4500	2529.84	1686.67	0.0	0.0	0.0	0.0	11.8	88.2	93.0	0.0	0.0	2.6	0.0	1.4	0.1	0.0	0.0	2.9
TW[illegible]	1718000	1.6	1400	2804.16	612.66	0.0	0.0	0.0	0.0	2.2	97.8	81.0	0.0	0.0	8.6	0.0	6.7	0.0	0.0	0.0	3.7

Table 2. Mean annual meteorological, hydrological and nutrient values for 1976/77 - 1983/84 for each of the 32 study catchments. Abbreviations and units are described in the text. Standard deviations are shown beneath the means.

STRM	TEMP	PREC	HUMID	BASE	QICK	RUN	MAXM	SPFL	YILD	NH_4	NO_3	TON	TP
BC1	4.44	1.05	63.07	0.20	0.22	0.42	16.23	0.57	0.40	347.0	2628.3	5770.3	80.2
	0.64	0.09	18.62	0.06	0.14	0.11	6.22	0.19	0.09	294.6	1028.9	2666.5	33.5
BE1	4.53	1.05	65.17	0.37	0.16	0.53	10.50	0.52	0.50	992.8	4838.2	14264.9	243.5
	0.61	0.12	15.05	0.03	0.15	0.14	2.27	0.14	0.09	253.0	1103.0	5252.1	68.8
CB1	4.38	1.11	63.15	0.26	0.30	0.57	15.33	0.57	0.51	380.0	1391.1	7635.6	124.8
	0.65	0.15	18.49	0.06	0.17	0.16	5.28	0.18	0.13	260.3	726.6	2004.3	27.3
CB2	4.38	1.11	63.15	0.28	0.24	0.52	13.38	0.54	0.47	1298.1	3036.7	15944.7	396.9
	0.65	0.15	18.49	0.07	0.09	0.10	4.34	0.17	0.06	1135.5	4799.3	2911.1	95.9
CN1	4.50	1.05	65.74	0.32	0.28	0.60	11.34	0.47	0.53	2124.8	1980.9	14605.2	277.3
	0.68	0.12	14.02	0.03	0.14	0.11	4.88	0.12	0.05	263.8	503.8	2642.7	46.6
DE10	4.34	1.10	65.55	0.25	0.32	0.57	13.46	0.55	0.51	659.0	4232.1	15825.8	401.7
	0.66	0.14	14.49	0.05	0.12	0.10	3.09	0.14	0.05	527.2	5910.8	3417.2	119.7
DE11	4.34	1.10	65.55	0.24	0.35	0.59	14.16	0.55	0.54	723.8	1757.3	18072.7	475.0
	0.66	0.14	14.49	0.04	0.12	0.12	4.72	1.06	0.08	320.2	1725.8	5466.5	217.4
DE5	4.34	1.10	65.55	0.25	0.38	0.62	12.52	0.56	0.57	1410.7	582.8	20106.8	929.3
	0.66	0.14	14.49	0.05	0.14	0.12	3.69	0.15	0.09	567.0	277.9	4571.2	467.4
DE6	4.34	1.10	65.55	0.26	0.36	0.62	13.47	0.55	0.56	3721.2	918.2	22172.1	1129.1
	0.66	0.14	14.49	0.05	0.09	0.11	4.01	0.15	0.05	2029.5	645.4	5595.8	656.5
DE8	4.34	1.10	65.55	0.26	0.27	0.53	11.23	0.52	0.47	585.3	1044.2	16664.1	232.5
	0.66	0.14	14.49	0.07	0.20	0.19	5.02	0.15	0.14	452.8	516.8	6389.2	87.6
DK1	4.47	0.97	59.55	0.46	0.07	0.52	8.46	0.60	0.51	464.1	3558.7	10070.3	119.1
	0.60	0.10	17.64	0.03	0.03	0.00	2.81	0.13	0.02	106.0	1157.4	2725.2	32.3
HAL12	4.42	0.99	58.44	0.37	0.18	0.55	11.57	0.60	0.53	540.3	16999.4	13149.8	292.9
	0.62	0.12	18.26	0.05	0.05	0.08	1.71	0.10	0.06	58.0	3816.8	4009.0	64.0
HD1	4.41	0.96	59.24	0.24	0.29	0.54	13.63	0.68	0.54	1283.0	7906.4	19478.9	362.7
	0.65	0.10	17.76	0.08	0.07	0.06	1.01	0.15	0.04	697.2	4553.3	5235.6	163.2
HP3	4.95	1.06	62.93	0.28	0.30	0.58	14.64	0.51	0.55	1026.9	8793.4	13978.3	420.3
	0.56	0.12	18.78	0.02	0.12	0.12	3.89	0.11	0.08	733.1	5818.2	3648.7	110.3
HP3A	4.95	1.06	62.93	0.26	0.35	0.61	16.91	0.54	0.58	530.4	20651.0	9400.1	148.8
	0.56	0.12	18.78	0.03	0.11	0.14	3.79	0.14	0.13	410.3	16468.3	3240.6	50.4
HP4	4.95	1.06	62.93	0.30	0.27	0.57	11.53	0.51	0.54	1821.4	4057.6	12039.6	297.1
	0.56	0.12	18.78	0.04	0.11	0.12	3.91	0.13	0.10	795.7	1344.9	4180.0	56.6

Table 2. (cont'd)

STRM	TEMP	PREC	HUMID	BASE	QICK	RUN	MAXM	SPFL	YILD	NH_4	NO_3	TON	TP
HP5	4.95	1.06	62.93	0.24	0.37	0.61	14.23	0.53	0.58	1413.7	5380.9	16012.1	325.5
	0.56	0.12	18.78	0.08	0.13	0.12	4.63	0.15	0.11	614.8	2545.4	3181.2	58.3
HP6	4.95	1.06	62.93	0.25	0.39	0.65	14.28	0.53	0.61	1418.9	10437.9	12255.1	278.0
	0.56	0.12	18.78	0.04	0.10	0.12	4.98	0.15	0.10	837.7	3870.6	3289.9	45.7
HP6A	4.95	1.06	62.93	0.22	0.29	0.51	18.38	0.60	0.48	377.2	1075.4	10044.4	201.4
	0.56	0.12	18.78	0.06	0.08	0.11	5.83	0.18	0.08	294.2	548.3	3421.6	109.6
JY1	4.07	1.05	57.39	0.24	0.20	0.44	12.60	0.57	0.42	678.1	33564.6	8204.9	146.7
	0.63	0.11	19.50	0.03	0.07	0.10	2.37	0.05	0.06	385.2	27128.9	3064.4	23.0
JY3	4.07	1.05	57.39	0.43	0.05	0.48	10.36	0.58	0.46	2684.8	6555.1	12909.5	312.2
	0.63	0.11	19.50	0.09	0.10	0.09	4.67	0.10	0.06	584.8	3920.9	5009.3	50.0
JY4	4.07	1.05	57.39	0.27	0.14	0.41	11.57	0.69	0.39	727.1	14090.9	8804.9	133.1
	0.63	0.11	19.50	0.12	0.09	0.11	1.69	0.09	0.08	117.6	1778.5	4479.7	31.7
ME1	4.61	1.02	55.94	0.40	0.12	0.52	8.27	0.58	0.52	1186.5	7971.0	12735.7	225.9
	0.67	0.16	19.90	0.07	0.12	0.13	1.05	0.10	0.07	505.7	3672.8	4774.1	23.3
PC1	4.45	1.12	72.61	0.18	0.44	0.62	14.43	0.49	0.55	1670.4	17076.0	49097.2	174.6
	0.65	0.10	1.28	0.06	0.20	0.14	4.76	0.17	0.08	1862.0	22809.6	12661.4	36.7
PT1	4.45	1.10	72.61	0.26	0.29	0.55	15.71	0.54	0.50	465.2	5381.9	6815.0	65.5
	0.64	0.12	1.28	0.04	0.07	0.09	5.87	0.17	0.08	321.1	3026.2	3513.7	21.5
RC1	4.47	1.10	63.02	0.23	0.33	0.56	14.18	0.55	0.51	3139.0	5514.3	9551.8	197.1
	0.63	0.15	18.71	0.08	0.15	0.11	2.35	0.18	0.07	2194.0	5301.6	3455.7	61.6
RC2	4.47	1.10	63.02	0.19	0.35	0.54	13.92	0.54	0.49	853.1	1004.8	14756.4	185.7
	0.63	0.15	18.71	0.05	0.12	0.12	5.27	0.15	0.05	497.9	397.1	3424.0	38.0
RC3	4.47	1.10	63.02	0.38	0.27	0.64	10.74	0.51	0.59	1899.2	9883.9	13860.2	255.2
	0.63	0.15	18.71	0.09	0.10	0.12	2.22	0.14	0.09	1215.9	11178.7	4097.4	57.9
RC4	4.47	1.10	63.02	0.34	0.20	0.54	10.87	0.49	0.49	3725.0	5069.2	13185.0	360.3
	0.63	0.15	18.71	0.08	0.10	0.10	3.15	0.12	0.06	1864.4	1930.0	3596.2	56.0
TBAY1	4.49	1.13	72.61	0.12	0.49	0.61	22.98	0.68	0.55	586.8	25495.9	9994.0	128.3
	0.59	0.10	1.38	0.04	0.25	0.27	7.14	0.18	0.24	351.2	32893.2	5358.8	52.9
TWN11	4.55	1.05	65.71	0.40	0.16	0.57	9.56	0.48	0.52	1931.9	3831.2	14936.8	264.7
	0.60	0.12	14.06	0.02	0.12	0.11	2.50	0.12	0.07	726.6	1075.4	4237.1	66.0
TWS1	4.55	1.06	65.74	0.40	0.14	0.54	9.62	0.49	0.50	3100.1	2736.9	14868.7	266.9
	0.60	0.12	14.02	0.04	0.13	0.11	3.51	0.14	0.07	1163.2	729.1	3793.0	43.6

Table 3. Pearson correlation coefficients using annual data (256 stream-years).

	TP	NO_3	NH_4	TON
TP		-0.14	0.45	0.41
NO_3			0.03	-0.07
NH_4				0.24
YIELD	0.24	0.19	0.18	0.47
BASEFLOW	0.04	0.01	0.31	0.03
QUICKFLOW	0.20	0.05	-0.08	0.46
RUNOFF	0.26	0.07	0.12	0.55
PEAT	0.63	-0.23	0.09	0.38
POND	-0.18	-0.08	0.35	-0.16
MTLLPL	-0.28	0.30	-0.01	-0.35
GRADE	-0.30	0.39	-0.27	-0.21
BHG	-0.33	0.21	-0.04	-0.14
MIG	0.52	-0.24	0.05	0.27

Table 4. Pearson correlation coefficients using 8 year averages for each stream (n=32 for all parameters).

	TP	NO_3	NH_4	TON
TP		-0.33	0.47	0.33
NO_3			-0.24	-0.01
NH_4				0.26
HUMID	0.05	-0.09	0.03	0.38
QUICKFLOW	0.23	0.13	-0.09	0.35
RUNOFF	0.39	-0.07	0.23	0.40
SPRINGFLOW	-0.11	0.32	-0.42	-0.29
MAXM	-0.12	0.28	-0.37	-0.08
YIELD	0.35	-0.02	0.18	0.33
PEAT	0.75	-0.34	0.17	0.38
POND	-0.16	-0.18	0.45	-0.15
MTLLPL	-0.30	0.42	-0.03	-0.37
GRADE	-0.34	0.61	-0.35	-0.18
BHG	-0.36	0.34	-0.04	-0.08
MIG	0.62	-0.36	0.11	0.24

Table 5. Summary of regession analysis using data set A (256 stream-years) and untransformed variables. Independent variables are listed in the order in which they are accepted into a stepwise procedure.

Dependent Variable	R^2	Independent Variables
TP (without N fractions)	0.49	peat, rock, runoff, road, wash, grade, sand
TP (with all N)	0.73	peat, NH_4, springflow, marb, strml, rock, as, wash, humid, esker, grade, precip, maxm, ttllrr, road, mig, dior, drum
TP (with NH_4 only)	0.73	peat, NH_4, springflow, marb, strml, rock, as, wash, grade, maxm, mtllpl, esker, bhg, road, drum, yield, quickflow
TP (with TON only)	0.51	peat, TON, rock, road, baseflow, gmam, wash
NO_3^- (w/o N or TP)	0.43	grade, temp, yield, maxm, mtllpl, marb, pond, road, gmam, dior
NO_3^- (w/o N, with TP)	0.43	grade, temp, yield, maxm, mtllpl, marb, pond, road, gmam, dior
NO_3^- (with N, w/o TP)	0.43	grade, dior, maxm, temp, yield, mtllpl, marb, pond, road, gmam
NO_3^- (with N & TP)	0.43	grade, dior, maxm, temp, yield, mtllpl, marb, pond, road, gmam
NH_4^+ (w/o N or TP)	0.45	pond, peat, temp, humid, marb, yield, rock, grade, mig, road, drum, sand, mtllpl
NH_4^+ (w/o N, with TP)	0.65	TP, pond, temp, humid, mig, marb, strml, esker, road, precip, runoff, maxm, rock
NH_4^+ (with N, w/o TP)	0.43	pond, TON, temp, humid, marb, rock, grade, yield, quickflow, esker
NH_4^+ (with N & TP)	0.65	TP, pond, temp, humid, mig, marb, strml, esker, road, precip, runoff, maxm, rock

Table 5. (cont'd)

Dependent Variable	R^2	Independent Variables
TON (w/o N or TP)	0.52	runoff, mtllpl, peat, humid, dior, wash
TON (w/o N, with TP)	0.54	runoff, mtllpl, TP, humid, peat, dior, bhg
TON (with N, w/o TP)	0.54	runoff, mtllpl, peat, humid, dior, wash, NH_4, pond
TON (with N & TP)	0.54	runoff, mtllpl, TP, humid, peat, dior, bhg

Table 6. Summary of regession analysis using average annual data (B) and untransformed variables. Independent variables are listed in the order in which they are accepted into a stepwise procedure.

Dependent Variable	R^2	Independent Variables
TP (without N fractions)	0.64	peat, humid, rock
TP (with N fractions)	0.80	peat, NH_4, precip, gmam, road
NO_3^- (w/o N or TP)	0.65	grade, humid, springflow, temp, yield
NO_3^- (w/o N, with TP)	0.65	grade, humid, springflow, temp, yield
NO_3^- (with N, w/o TP)	0.74	grade, dior, humid, springflow, TON, wash, sand
NO_3^- (with N & TP)	0.74	grade, dior, humid, springflow, TON, wash, sand
NH_4^+ (w/o N or TP)	0.41	pond, maxm, marb, runoff
NH_4^+ (w/o N, with TP)	0.68	TP, pond, mig, marb, maxm
NH_4^+ (with N, w/o TP)	0.55	pond, TON, marb, humid, rock, precip
NH_4^+ (with N & TP)	0.68	TP, pond, mig, marb, maxm
TON (w/o N or TP)	0.30	runoff, mtllpl
TON (w/o N, with TP)	0.30	runoff, mtllpl
TON (with N, w/o TP)	0.30	runoff, mtllpl
TON (with N & TP)	0.30	runoff, mtllpl

Table 7. Summary of regession analysis using average annual data set B (excluding PC1, n=31) and untransformed variables. Independent variables are listed in the order in which they are accepted into a stepwise procedure. +, - or 0 indicates changes in R^2.

Dependent Variable	R^2		Independent Variables
TP (without N fractions)	0.64	0	peat, maxm, wash
TP (with N fractions)	0.87	+	TON, peat, NH_4, pond, marb, strml, rock
TP (with NH_4 only)	0.89	+	peat, NH_4, pond, marb, strml, wash, as, grade, rock
NO_3^- (w/o N or TP)	0.73	+	grade, humid, dior, wash, sand, springflow
NO_3^- (w/o N, with TP)	0.73	+	grade, humid, dior, wash, sand, springflow
NO_3^- (with N, w/o TP)	0.73	-	grade, humid, dior, wash, sand, springflow
NO_3^- (with N & TP)	0.73	-	grade, humid, dior, wash, sand, springflow
NH_4^+ (w/o N or TP)	0.37	+	pond, maxm, marb
NH_4^+ (w/o N, with TP)	0.72	+	TP, pond, mig, marb, quickflow
NH_4^+ (with N, w/o TP)	0.68	+	pond, TON, marb, humid, rock, precip, mig
NH_4^+ (with N & TP)	0.72	+	TP, pond, mig, marb, quickflow
TON (w/o N or TP)	0.86	+	peat, wash, maxm, runoff
TON (w/o N, with TP)	0.89	+	TP, mtllpl, wash, springflow, peat, dior
TON (with N, w/o TP)	0.86	+	peat, wash, maxm, runoff
TON (with N & TP)	0.90	+	TP, mtllpl, wash, springflow, peat, NO_3

Table 8. Pearson correlation coefficients using 8 year averages for each stream, excluding PC1 (n=31 for all parameters).

	TP	NO_3	NH_4	TON
TP		-0.31	0.47	0.80
NO_3			-0.26	-0.39
NH_4				0.41
HUMID	0.10	-0.20	0.01	0.08
QUICKFLOW	0.27	0.06	-0.11	0.19
RUNOFF	0.42	-0.12	0.23	0.45
SPRINGFLOW	-0.14	0.39	-0.42	-0.21
MAXM	-0.11	0.27	-0.37	-0.28
YIELD	0.37	-0.06	0.17	0.42
PEAT	0.75	-0.36	0.17	0.71
POND	-0.18	-0.16	0.46	-0.09
MTLLPL	-0.32	0.46	-0.02	-0.54
GRADE	-0.34	0.61	-0.36	-0.43
BHG	-0.35	0.32	-0.05	-0.43
MIG	0.62	-0.35	0.11	0.60

Table 9. Summary of regession analysis using average annual data (B) with transformed and untransformed variables (excluding PC1, n=31). Independent variables are listed in the order in which they are accepted into a stepwise procedure.

Dependent Variable	R^2	Independent Variables
TP (w/o N)	0.85	$peat^2$, 1/baseflow, $wash^2$, 1/strml, 1/runoff, strml, tllcrb
TP (with NH_4)	0.95	$peat^2$, NH_4^2, 1/precip, pond, $gmam^2$, tllcrb, 1/quickflow, baseflow, $humid^2$, gmam, yield, $rock^2$
NO_3^- (with N & TP)	0.74	grade, 1/humid, dior, $springflow^2$, 1/grade, 1/astrml
NH_4^+ (w/o N or TP)	0.42	pond, $peat^2$, 1/quickflow, marb
NH_4^+ (w/o N, with TP)	0.92	1/TP, pond, TP^2, $peat^2$, marb, (with N & TP)1/quickflow, $astrml^2$, $strml^2$, drum, 1/strml, astrml
NH_4^+ (with N, w/o TP)	0.65	pond, TON^2, 1/quickflow, mtllpl, $mtllpl^2$
TON (w/o N or TP)	0.86	peat, $wash^2$, maxm, 1/runoff
TON (w/o N, with TP)	0.95	1/TP, TP, wash, peat, 1/maxm, humid, $rock^2$, road
TON (with N, w/o TP)	0.99	peat, 1/NH_4, $wash^2$, marb, $road^2$, $ttllrr^2$, 1/springflow, $pond^2$, 1/humid, humid, NO_3^2, $quickflow^2$, $humid^2$, $strml^2$, 1/precip, wash
TON (with N & TP)	0 .96	1/TP, TP, wash, peat, 1/maxm, humid, $rock^2$, NH_4^2, $peat^2$, mig^2

Table 10. Recommended regression equation for long-term mean annual TP export (n=31, excluding PC1 and bedrock geology).

Variable	Coefficient	Standard Error	R^2	F	Prob>F
$peat^2$	1.115	0.128	0.71	19.22	0.0001
1/baseflow	-113.69	27.14	0.74		
$wash^2$	0.023	0.010	0.77		
1/strml	241743	70003	0.79		
1/runoff	-213.36	96.90	0.81		
strml	0.101	0.038	0.83		
tllcrb	- 1.544	0.760	0.85		
intercept	634.0	206.55	-		

Table 11. Recommended regression equation for long-term mean annual NO_3^- export /(n=31, excluding PC1 and bedrock geology).

Variable	Coefficient	Standard Error	R^2	F	Prob>F
grade	1671.28	329.96	0.37	14.29	0.0001
humid	-1624.9	323.10	0.51		
mtllpl	81.79	32.14	0.57		
tllcrb	127.03	29.39	0.61		
temp	-18859.0	3918.6	0.67		
quickflow	51548.3	13100.3	0.75		
springflow	-82870.4	29881.7	0.81		
intercept	215199.2	43040.1	-		

Table 12. Recommended regression equation for long-term mean annual NH_4^+ export (n=31, excluding PC1 and bedrock geology).

Variable	Coefficient	Standard Error	R^2	F	Prob>F
1/TP	-178261.6	36984.2	0.24	14.29	0.0001
pond	286.25	52.00	0.48		
TP^2	0.003	0.0006	0.59		
$peat^2$	-3.83	1.11	0.67		
1/precip	-7566.0	2888.4	0.71		
1/quickflow	166.54	32.02	0.77		
area	-0.0002	0.00007	0.81		
intercept	8538.9	2758.2	-		

Table 13. Recommended regression equation for long-term mean annual TON export ($n=31$, excluding PC1 and bedrock geology).

Variable	Coefficient	Standard Error	R^2	F	Prob>F
peat	404.78	45.48	0.50	41.55	0.0001
$wash^2$	0.96	0.162	0.68		
maxm	-540.48	95.05	0.83		
1/runoff	-3892.1	1489.39	0.86		
intercept	24424.0	3262.1	-		

Table 14. Linear regression R^2 for TP export equation recommended in Table 10 using running averages of annual values from 1976/77 to 1983/84.

No. consecutive years sampling	R^2 mean	(sd)	R^2 range	n
1	0.68	(0.12)	0.51 - 0.84	8
2	0.72	(0.11)	0.62 - 0.87	7
3	0.74	(0.10)	0.63 - 0.87	6
4	0.77	(0.09)	0.68 - 0.90	5
5	0.78	(0.06)	0.70 - 0.84	4
6	0.81	(0.02)	0.80 - 0.83	3
7	0.83		0.81 - 0.85	2
8	0.85			1

Table 15. R^2 values for TP export using data subsets of four and five consecutive years. Regressions were performed using both the stepwise model and the independent variables recommended in Table 10.

	Recommended	Stepwise
<u>4 consecutive yrs</u>		
1976/77-1979/80	0.69	0.53
1977/78-1980/81	0.68	0.50
1978/79-1981/82	0.77	0.69
1979/80-1982/83	0.79	0.77
1980/81-1983/84	<u>0.90</u>	<u>1.00</u>
Mean R^2	0.77	0.70
<u>6 consecutive yrs</u>		
1976/77-1981/82	0.81	0.77
1977/78-1982/83	0.80	0.71
1978/79-1983/84	<u>0.83</u>	<u>0.89</u>
Mean R^2	0.82	0.79

APPENDIX

DATA TABLES

Definition of Terms:

TEMP	- mean annual air temperature, °C
PRECIP	- annual precipitation, m
HUMID	- mean annual relative humidity, %
RUNOFF	- annual stream discharge, m/yr
BASE	- annual stream baseflow defined as the lowest observed runoff value in one month (times 12), m/yr
QUICK	- annual stream quickflow (runoff-baseflow), m/yr
MAXM	- ratio of maximum to minimum stream discharge rate
SPRING	- proportion of stream flow occurring as springflow February 1 - May 1
YIELD	- ratio of runoff to precipitation
NH4	- annual stream export of NH_4, ug-at/m^2/yr
NO3	- annual stream export of NO_3, ug-at/m^2/yr
TON	- annual stream export of total organic nitrogen, ug-at/m^2/yr
TP	- annual stream export of total phosphorus, ug-at/m^2/yr

Table A1. Annual data for BC1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.85	0.937	75.72	0.104	0.315	0.419	13.90	0.960	0.447	558.88	3431.23	9725.34	68.27
77.78	3.77	1.029	72.35	0.179	0.081	0.260	13.60	0.507	0.253	312.19	4061.26	2613.59	74.18
78.79	4.34	1.052	35.49	0.306	0.000	0.306	15.50	0.544	0.291	474.92	1428.86	4811.67	45.45
79.80	5.13	1.099	30.65	0.176	0.351	0.527	12.50	0.470	0.479	919.72	3795.00	9947.22	156.11
80.81	4.00	1.072	73.83	0.204	0.239	0.443	18.80	0.519	0.413	255.63	2332.84	4871.54	64.86
81.82	4.15	1.012	72.80	0.252	0.107	0.359	30.60	0.658	0.355	111.55	2536.63	4989.41	59.79
82.83	5.56	1.230	73.12	0.217	0.397	0.614	11.40	0.292	0.499	97.36	2009.97	5509.39	85.42
83.84	4.69	0.992	70.60	0.189	0.249	0.438	13.50	0.635	0.442	45.59	1430.54	3693.84	87.18

Table A2. Annual data for CB1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.77	0.864	75.73	0.143	0.330	0.473	18.70	0.870	0.548	479.87	366.86	6068.15	84.08
77.78	3.69	0.963	72.39	0.326	0.301	0.627	9.37	0.569	0.651	693.41	2355.41	5338.83	121.40
78.79	4.26	1.268	35.80	0.272	0.561	0.833	22.80	0.736	0.657	763.49	956.16	10707.46	124.31
79.80	5.08	1.188	30.92	0.227	0.528	0.755	12.40	0.430	0.636	406.29	1167.43	8843.49	114.12
80.81	3.93	1.203	73.83	0.308	0.180	0.488	12.90	0.486	0.406	334.79	1517.17	9579.03	153.33
81.82	4.13	1.007	72.80	0.297	0.114	0.411	22.70	0.566	0.408	217.26	2453.94	7281.08	156.30
82.83	5.52	1.231	73.12	0.273	0.273	0.546	12.30	0.293	0.444	90.25	1488.51	7972.98	150.85
83.84	4.66	1.152	70.60	0.258	0.135	0.393	11.50	0.600	0.341	54.91	822.95	5295.53	94.16

Table A3. Annual data for CB2 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.77	0.864	75.73	0.123	0.236	0.359	18.50	0.850	0.416	1896.36	288.12	17126.98	380.67
77.78	3.69	0.963	72.39	0.331	0.185	0.516	7.58	0.450	0.535	2879.54	14838.12	13879.07	401.39
78.79	4.26	1.268	35.80	0.334	0.172	0.506	12.90	0.678	0.399	866.62	1577.62	16343.66	364.65
79.80	5.08	1.188	30.92	0.301	0.305	0.606	15.90	0.490	0.510	2944.03	1935.47	19739.04	542.07
80.81	3.93	1.203	73.83	0.290	0.337	0.627	10.90	0.431	0.521	964.25	1367.86	19587.06	511.32
81.82	4.13	1.007	72.80	0.344	0.112	0.456	19.10	0.553	0.453	436.41	1881.04	13452.20	377.58
82.83	5.52	1.231	73.12	0.243	0.390	0.633	13.90	0.282	0.514	221.16	873.66	15913.86	366.52
83.84	4.66	1.152	70.60	0.262	0.196	0.458	8.28	0.594	0.398	176.78	1531.66	11515.38	230.72

Table A4. Annual data for CN1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.19	0.839	75.67	.	.	.	.	.	.	.	.	.	.
77.78	3.51	0.988	73.53	.	.	.	.	.	.	.	.	.	.
78.79	4.58	1.007	46.39	.	.	.	.	.	.	.	.	.	.
79.80	5.27	1.087	40.22	.	.	.	.	.	.	.	.	.	
80.81	4.03	1.199	73.83	0.295	0.353	0.648	13.30	0.481	0.541	2483.50	2186.72	17521.98	296.37
81.82	4.17	0.988	72.80	0.341	0.121	0.462	17.30	0.573	0.467	2092.79	2510.61	11972.57	215.15
82.83	5.58	1.213	73.00	0.283	0.432	0.715	7.98	0.295	0.589	1848.08	1323.42	16117.34	325.44
83.84	4.64	1.061	70.47	0.350	0.212	0.562	6.78	0.538	0.530	2074.80	1902.89	12809.06	272.39

Table A5. Annual data for DE5 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.87	0.864	75.88	0.194	0.391	0.585	19.10	0.790	0.677	1264.30	549.60	16709.53	694.80
77.78	3.53	0.949	73.64	0.231	0.299	0.530	11.10	0.555	0.559	1839.87	833.92	13310.38	522.60
78.79	4.14	1.188	45.56	0.303	0.330	0.633	13.00	0.680	0.533	1277.27	428.99	20535.82	414.29
79.80	5.01	1.128	39.15	0.179	0.575	0.754	12.10	0.580	0.668	1096.55	693.17	28246.11	656.86
80.81	3.81	1.199	73.84	0.281	0.497	0.778	11.40	0.438	0.649	1619.38	1068.64	24014.41	807.83
81.82	4.12	1.058	72.80	0.326	0.129	0.455	16.30	0.585	0.430	2078.47	530.70	17703.09	1319.56
82.83	5.44	1.265	73.02	0.244	0.471	0.715	7.32	0.289	0.565	584.70	186.92	20893.18	1253.72
83.84	4.76	1.177	70.49	0.217	0.329	0.546	9.85	0.588	0.464	2325.43	370.25	19441.99	1764.40

Table A6. Annual data for DE6 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.87	0.864	75.88	0.179	0.273	0.452	16.70	0.750	0.523	2133.65	532.67	17549.08	559.33
77.78	3.53	0.949	73.64	0.223	0.318	0.541	11.90	0.587	0.570	2402.14	2398.92	17773.75	872.73
78.79	4.14	1.188	45.56	0.317	0.375	0.692	13.00	0.697	0.582	5110.11	466.84	25584.55	1148.16
79.80	5.01	1.128	39.15	0.244	0.419	0.663	20.70	0.510	0.588	4751.00	1043.61	29543.32	1711.05
80.81	3.81	1.199	73.84	0.300	0.460	0.760	11.80	0.408	0.634	7473.10	852.27	30495.20	2440.38
81.82	4.12	1.058	72.80	0.308	0.220	0.528	15.60	0.585	0.499	4141.54	954.53	18177.06	1099.27
82.83	5.44	1.265	73.02	0.248	0.497	0.745	9.46	0.290	0.589	1358.43	352.89	21214.57	718.32
83.84	4.76	1.177	70.49	0.254	0.320	0.574	8.59	0.584	0.488	2399.95	744.04	17039.44	483.24

Table A7. Annual data for DE8 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXH	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.87	0.864	75.88	0.210	0.068	0.278	11.50	0.760	0.322	474.41	352.79	9968.65	160.60
77.78	3.53	0.949	73.64	0.343	0.000	0.343	7.16	0.374	0.362	747.79	926.40	8586.89	189.67
78.79	4.14	1.188	45.56	0.263	0.062	0.325	6.91	0.681	0.274	856.05	248.54	11501.67	111.90
79.80	5.01	1.128	39.15	0.180	0.418	0.598	13.70	0.480	0.530	1303.13	1182.98	20706.56	239.84
80.81	3.81	1.199	73.84	0.309	0.450	0.759	13.00	0.448	0.633	1551.37	1629.77	26829.75	374.08
81.82	4.12	1.058	72.80	0.203	0.392	0.595	21.70	0.548	0.562	1185.72	1602.19	20593.26	332.39
82.83	5.44	1.265	73.02	0.324	0.455	0.779	8.40	0.322	0.616	474.75	1108.29	20042.15	257.00
83.84	4.76	1.177	70.49	0.267	0.293	0.560	7.47	0.548	0.476	272.81	1302.84	15083.60	194.68

Table A8. Annual data for DE10 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.87	0.864	75.88	0.246	0.201	0.447	13.40	0.650	0.517	1407.84	13232.48	17569.79	625.74
77.78	3.53	0.949	73.64	0.208	0.246	0.454	10.80	0.550	0.478	1229.84	14270.69	11538.42	454.19
78.79	4.14	1.188	45.56	0.328	0.251	0.579	11.90	0.749	0.487	823.92	2338.73	17025.04	359.58
79.80	5.01	1.128	39.15	0.195	0.432	0.627	18.50	0.520	0.556	942.36	1026.15	20174.82	411.55
80.81	3.81	1.199	73.84	0.267	0.406	0.673	11.90	0.451	0.561	568.99	1202.87	19386.15	454.85
81.82	4.12	1.058	72.80	0.328	0.190	0.518	18.10	0.571	0.490	155.34	716.33	12746.82	373.65
82.83	5.44	1.265	73.02	0.220	0.506	0.726	12.10	0.298	0.574	76.78	383.61	16504.92	319.49
83.84	4.76	1.177	70.49	0.207	0.294	0.501	11.00	0.615	0.426	66.67	686.09	11660.71	214.33

Table A9. Annual data for DE11 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.87	0.864	75.88	0.236	0.190	0.426	19.10	0.770	0.493	422.63	1447.59	14513.70	298.27
77.78	3.53	0.949	73.64	0.238	0.317	0.555	9.30	0.512	0.585	823.90	5989.20	12039.82	375.53
78.79	4.14	1.188	45.56	0.308	0.410	0.718	10.60	0.711	0.604	1096.21	1044.33	24992.22	308.57
79.80	5.01	1.128	39.15	0.217	0.501	0.718	21.70	0.470	0.637	843.37	962.89	24095.99	393.29
80.81	3.81	1.199	73.84	0.257	0.386	0.643	16.00	0.455	0.536	609.60	1289.00	23148.21	848.15
81.82	4.12	1.058	72.80	0.277	0.234	0.511	15.90	0.578	0.483	1202.20	1481.38	15305.41	716.68
82.83	5.44	1.265	73.02	0.208	0.491	0.699	11.50	0.273	0.553	458.39	839.54	18884.84	593.47
83.84	4.76	1.177	70.49	0.201	0.273	0.474	9.18	0.637	0.403	334.40	1004.15	11601.44	266.11

Table A10. Annual data for HP3 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.276	0.130	0.406	17.00	0.630	0.449	579.37	2126.86	10843.61	408.58
77.78	4.29	0.906	71.98	0.315	0.122	0.437	12.10	0.607	0.483	1853.28	13436.51	8053.21	306.93
78.79	4.60	1.143	34.94	0.285	0.271	0.556	18.30	0.585	0.486	988.17	4381.83	14588.71	404.57
79.80	5.48	0.941	30.34	0.247	0.306	0.553	16.40	0.520	0.588	2094.79	5236.56	13396.40	352.43
80.81	4.42	1.104	73.83	0.283	0.447	0.730	11.70	0.426	0.661	1604.72	16274.03	19477.70	628.92
81.82	4.75	1.097	72.80	0.304	0.376	0.680	20.40	0.447	0.620	520.28	16877.31	17417.97	500.92
82.83	5.86	1.221	73.33	0.293	0.435	0.728	11.80	0.291	0.596	449.89	7009.84	15677.61	464.13
83.84	5.41	1.131	70.82	0.248	0.314	0.562	9.39	0.551	0.497	124.71	5004.66	12371.21	296.21

Table A11. Annual data for HP3A catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.197	0.102	0.299	17.80	0.780	0.331	218.90	2649.62	2840.51	77.31
77.78	4.29	0.906	71.98	0.268	0.402	0.670	11.50	0.604	0.740	1016.82	49764.13	10389.12	145.28
78.79	4.60	1.143	34.94	0.282	0.436	0.718	18.70	0.607	0.628	1177.98	11768.92	12244.52	119.31
79.80	5.48	0.941	30.34	0.224	0.380	0.604	14.40	0.550	0.642	679.25	8488.88	9876.86	121.34
80.81	4.42	1.104	73.83	0.279	0.440	0.719	20.30	0.450	0.652	614.52	37280.93	13287.04	225.35
81.82	4.75	1.097	72.80	0.272	0.373	0.645	22.20	0.472	0.588	307.81	30047.31	10334.78	204.11
82.83	5.86	1.221	73.33	0.295	0.390	0.685	12.40	0.306	0.561	113.82	14284.71	9088.50	181.62
83.84	5.41	1.131	70.82	0.236	0.299	0.535	18.00	0.588	0.473	114.31	10923.59	7139.74	116.12

Table A12. Annual data for HP4 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.273	0.111	0.384	14.40	0.730	0.425	1671.97	1344.81	7252.05	200.66
77.78	4.29	0.906	71.98	0.312	0.166	0.478	11.40	0.606	0.528	3158.29	5126.86	7739.30	280.87
78.79	4.60	1.143	34.94	0.349	0.414	0.763	12.60	0.518	0.667	2137.79	4860.48	16791.68	321.28
79.80	5.48	0.941	30.34	0.231	0.414	0.645	18.40	0.520	0.686	1258.83	4697.97	16799.83	295.55
80.81	4.42	1.104	73.83	0.366	0.291	0.657	7.71	0.435	0.595	1855.53	5072.26	16324.13	360.85
81.82	4.75	1.097	72.80	0.307	0.266	0.573	12.80	0.411	0.522	2593.96	4868.29	12488.42	350.75
82.83	5.86	1.221	73.33	0.313	0.284	0.597	6.76	0.320	0.489	1147.50	3467.02	10837.15	333.17
83.84	5.41	1.131	70.82	0.263	0.208	0.471	8.15	0.553	0.416	747.50	3023.51	8084.13	233.16

Table A13. Annual data for HP5 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.124	0.330	0.454	21.20	0.790	0.502	2358.65	1839.28	13260.48	392.74
77.78	4.29	0.906	71.98	0.273	0.173	0.446	12.00	0.478	0.492	1624.68	3818.17	10477.36	288.85
78.79	4.60	1.143	34.94	0.334	0.260	0.594	13.50	0.627	0.520	1771.99	3755.89	17971.01	404.63
79.80	5.48	0.941	30.34	0.170	0.574	0.744	18.40	0.560	0.791	1906.13	5718.00	19582.54	359.12
80.81	4.42	1.104	73.83	0.276	0.430	0.706	9.71	0.464	0.640	1322.35	5658.81	18155.36	315.48
81.82	4.75	1.097	72.80	0.333	0.338	0.671	18.90	0.446	0.611	921.05	7195.79	18192.61	318.94
82.83	5.86	1.221	73.33	0.249	0.489	0.738	11.10	0.283	0.604	895.28	4792.07	16883.36	292.89
83.84	5.41	1.131	70.82	0.197	0.330	0.527	9.07	0.606	0.466	509.36	10269.30	13574.06	228.71

Table A14. Annual data for HP6 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.188	0.245	0.433	22.60	0.800	0.480	714.96	3607.10	6626.55	241.24
77.78	4.29	0.906	71.98	0.251	0.316	0.567	13.60	0.622	0.626	1620.79	17701.13	9949.82	263.03
78.79	4.60	1.143	34.94	0.279	0.545	0.824	13.10	0.608	0.721	3223.83	10218.56	16719.13	319.63
79.80	5.48	0.941	30.34	0.207	0.492	0.699	16.20	0.500	0.743	1362.49	9467.86	14083.13	283.20
80.81	4.42	1.104	73.83	0.270	0.433	0.703	9.04	0.455	0.637	1718.81	10816.58	15157.24	346.36
81.82	4.75	1.097	72.80	0.261	0.439	0.700	19.90	0.414	0.638	1089.06	11804.36	13289.06	309.65
82.83	5.86	1.221	73.33	0.319	0.394	0.713	10.60	0.294	0.584	1108.36	10936.27	12406.68	254.13
83.84	5.41	1.131	70.82	0.257	0.281	0.538	9.19	0.574	0.476	513.19	8951.44	9808.98	207.01

Table A15. Annual data for HP6A catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.79	0.903	75.41	0.117	0.223	0.340	27.60	0.920	0.376	291.47	510.30	5964.43	144.12
77.78	4.29	0.906	71.98	0.192	0.221	0.413	12.80	0.631	0.456	648.67	2059.49	6327.17	154.89
78.79	4.60	1.143	34.94	0.299	0.244	0.543	17.10	0.706	0.475	826.72	1054.84	13081.30	176.96
79.80	5.48	0.941	30.34	0.289	0.278	0.567	15.20	0.540	0.602	606.08	1203.39	13050.75	389.72
80.81	4.42	1.104	73.83	0.220	0.428	0.648	22.70	0.534	0.587	409.80	1587.31	15235.23	362.73
81.82	4.75	1.097	72.80	0.239	0.272	0.511	24.70	0.505	0.466	106.66	912.06	9320.22	137.06
82.83	5.86	1.221	73.33	0.233	0.403	0.636	14.60	0.310	0.521	57.41	384.37	9707.50	125.79
83.84	5.41	1.131	70.82	0.185	0.254	0.439	12.30	0.628	0.388	70.59	891.19	7668.46	119.63

Table A16. Annual data for RC1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.91	0.858	75.74	0.149	0.337	0.486	16.90	0.850	0.566	3713.91	4025.55	7767.17	150.54
77.78	3.83	0.942	72.34	0.250	0.271	0.521	9.71	0.570	0.553	7165.02	18495.59	6683.31	225.22
78.79	4.37	1.277	35.27	0.317	0.336	0.653	13.70	0.635	0.511	4955.42	4674.17	13126.92	231.40
79.80	5.16	1.200	30.45	0.158	0.504	0.662	14.40	0.470	0.552	2274.64	4461.94	15626.25	303.12
80.81	4.04	1.199	73.83	0.212	0.370	0.582	14.50	0.477	0.486	3689.80	3152.79	10322.75	209.56
81.82	4.17	0.988	72.80	0.363	0.037	0.400	17.20	0.587	0.405	1207.21	2904.37	6020.29	120.92
82.83	5.58	1.213	73.11	0.188	0.527	0.715	14.10	0.228	0.589	621.25	2455.80	10296.12	210.11
83.84	4.71	1.103	70.59	0.175	0.290	0.465	12.90	0.592	0.422	1484.94	3944.45	6571.65	126.22

Table A17. Annual data for RC2 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.91	0.858	75.74	0.160	0.189	0.349	19.00	0.790	0.407	918.17	458.02	10906.35	156.30
77.78	3.83	0.942	72.34	0.142	0.303	0.445	7.76	0.540	0.473	1397.65	784.84	13212.48	202.33
78.79	4.37	1.277	35.27	0.283	0.366	0.649	8.69	0.596	0.508	1660.35	1021.63	19822.82	240.24
79.80	5.16	1.200	30.45	0.131	0.423	0.554	15.60	0.460	0.461	907.87	1695.45	17823.06	199.53
80.81	4.04	1.199	73.83	0.221	0.381	0.602	21.30	0.501	0.502	865.23	734.88	16009.91	213.23
81.82	4.17	0.988	72.80	0.241	0.217	0.458	18.10	0.589	0.463	458.06	1413.01	10925.83	126.58
82.83	5.58	1.213	73.11	0.162	0.557	0.719	11.90	0.259	0.593	434.17	829.69	17276.13	198.72
83.84	4.71	1.103	70.59	0.200	0.325	0.525	9.00	0.580	0.476	183.46	1100.52	12074.73	148.63

Table A18. Annual data for RC3 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.91	0.858	75.74	0.283	0.239	0.522	11.70	0.730	0.609	1270.51	6090.25	10622.68	197.29
77.78	3.83	0.942	72.34	0.438	0.280	0.718	6.60	0.419	0.763	3806.22	37058.02	15289.64	358.78
78.79	4.37	1.277	35.27	0.509	0.271	0.780	11.50	0.608	0.611	3773.19	9736.98	19104.80	294.81
79.80	5.16	1.200	30.45	0.338	0.418	0.756	11.00	0.440	0.630	1980.92	7957.76	20123.56	283.69
80.81	4.04	1.199	73.83	0.417	0.264	0.681	10.20	0.444	0.568	1304.09	5844.88	13657.56	239 63
81.82	4.17	0.988	72.80	0.420	0.073	0.493	14.50	0.539	0.499	994.00	5391.55	9883.77	233.66
82.83	5.58	1.213	73.11	0.346	0.347	0.693	10.80	0.274	0.571	1278.74	3695.06	12992.95	257.62
83.84	4.71	1.103	70.59	0.251	0.243	0.494	9.62	0.628	0.448	785.87	3296.36	9206.52	176.01

Table A19. Annual data for RC4 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.91	0.858	75.74	0.242	0.116	0.358	16.30	0.700	0.417	4650.50	2387.70	10642.93	377.80
77.78	3.83	0.942	72.34	0.464	0.086	0.550	7.60	0.469	0.584	6016.04	9023.47	8398.44	455.16
78.79	4.37	1.277	35.27	0.409	0.208	0.617	10.90	0.570	0.483	4730.30	5705.67	20226.27	368.19
79.80	5.16	1.200	30.45	0.297	0.285	0.582	11.00	0.450	0.485	4308.40	4825.31	14943.77	350.34
80.81	4.04	1.199	73.83	0.404	0.137	0.541	7.80	0.426	0.451	1756.14	3855.41	13130.78	313.51
81.82	4.17	0.988	72.80	0.335	0.120	0.455	14.70	0.525	0.460	5385.93	5452.79	12146.18	384.93
82.83	5.58	1.213	73.11	0.345	0.356	0.701	9.70	0.268	0.578	1730.39	4013.51	14909.73	369.67
83.84	4.71	1.103	70.59	0.241	0.270	0.511	8.97	0.535	0.463	1222.42	5290.01	11081.66	262.44

Table A20. Annual data for PC1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.82	1.199	73.83	.	.	.	.	.	.	.	44725.38	.	.
77.78	3.80	0.988	72.79	.	.	.	.	.	.	4156.81	48224.62	39000.98	.
78.79	4.34	1.213	73.15	.	.	.	.	.	.	.	.		.
79.80	5.16	1.117	70.63	.	.	.	.	.	.	3185.24	3468.71	68192.70	216.00
80.81	4.03	1.199	73.83	0.170	0.466	0.636	16.80	0.517	0.531	.	.	.	169.00
81.82	4.17	0.988	72.80	0.277	0.201	0.478	19.80	0.607	0.484	525.04	2421.37	43084.62	148.00
82.83	5.58	1.213	73.17	0.130	0.676	0.806	11.90	0.241	0.664	259.52	1296.62	55791.28	208.00
83.84	4.73	1.051	70.65	0.159	0.399	0.558	9.22	0.587	0.531	225.36	2319.26	39416.66	132.00

Table A21. Annual data for JY1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.80	0.917	75.38	0.201	0.113	0.314	13.20	0.580	0.342	325.53	5886.01	4371.79	127.64
77.78	3.45	1.044	72.90	0.250	0.168	0.418	10.70	0.585	0.400	542.65	70913.38	7405.79	126.07
78.79	4.13	1.176	43.36	0.281	0.246	0.527	10.80	0.614	0.448	1224.95	28996.80	11548.51	165.97
79.80	4.91	1.051	37.92	0.239	0.268	0.507	15.70	0.500	0.482	619.43	28462.26	9493.50	167.33
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A22. Annual data for JY3 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.80	0.917	75.38	0.400	0.000	0.400	15.30	0.710	0.436	.	699.07	.	345.63
77.78	3.45	1.044	72.90	0.412	0.000	0.412	7.66	0.572	0.394	3307.28	8273.43	7360.58	254.42
78.79	4.13	1.176	43.36	0.566	0.004	0.570	5.28	0.490	0.485	2600.36	9020.40	14269.52	361.57
79.80	4.91	1.051	37.92	0.361	0.188	0.549	13.20	0.530	0.522	2146.77	8227.48	17096.29	287.34
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A23. Annual data for JY4 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.80	0.917	75.38	0.119	0.177	0.296	13.80	0.800	0.323	.	.	.	.
77.78	3.45	1.044	72.90	0.289	0.054	0.343	9.98	0.606	0.328	627.66	13696.04	4546.47	96.52
78.79	4.13	1.176	43.36	0.405	0.085	0.490	10.60	0.708	0.417	856.89	16033.65	8391.08	151.71
79.80	4.91	1.051	37.92	0.256	0.255	0.511	11.90	0.630	0.486	696.89	12542.94	13477.12	151.18
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A24. Annual data for BE1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.16	0.837	75.65	0.353	0.000	0.353	11.90	0.640	0.422	1153.26	2687.72	9363.50	189.08
77.78	3.86	0.972	73.23	0.365	0.086	0.451	9.23	0.560	0.464	1389.56	5686.35	9546.14	188.63
78.79	4.55	1.015	43.95	0.410	0.163	0.573	11.80	0.650	0.564	1220.60	4776.58	18942.30	212.98
79.80	5.25	1.090	38.09	0.367	0.225	0.592	9.91	0.450	0.543	961.38	5025.39	20925.80	362.98
80.81	4.03	1.199	73.83	0.412	0.280	0.692	6.67	0.390	0.577	874.21	5585.16	20041.33	272.80
81.82	4.17	0.988	72.79	0.412	0.055	0.467	14.40	0.531	0.473	778.48	6197.54	10805.39	184.60
82.83	5.58	1.213	73.17	0.337	0.405	0.742	10.30	0.267	0.612	960.74	4758.61	15926.55	324 97
83.84	4.64	1.061	70.65	0.335	0.049	0.384	9.75	0.641	0.362	604.36	3988.54	8567.85	211 91

Table A25. Annual data for DK1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.18	0.829	75.65	.	.	.	.	.	.	.	.	.	.
77.78	3.87	0.986	73.65	0.476	0.045	0.521	6.85	0.560	0.528	606.29	4853.70	6988.61	134.76
78.79	4.60	1.005	47.59	0.423	0.104	0.527	11.70	0.750	0.524	430.17	2625.22	11059.71	81.93
79.80	5.25	1.074	41.32	0.466	0.056	0.522	6.83	0.500	0.486	415.92	3197.20	12162.47	140.60
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A26. Annual data for HD1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.11	0.812	75.50	.	.	.	.	.	.	.	.	.	.
77.78	3.71	0.963	73.43	0.162	0.316	0.478	12.70	0.700	0.496	591.63	13064.19	13675.91	210.20
78.79	4.60	1.007	47.00	0.328	0.212	0.540	14.70	0.810	0.536	1985.81	4443.87	20912.23	343.05
79.80	5.20	1.043	41.05	0.244	0.354	0.598	13.50	0.520	0.573	1271.54	6211.28	23848.50	534.76
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A27. Annual data for HAL12 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.09	0.817	75.24	.	.	.	.	.	.	.	.	.	.
77.78	3.80	0.975	72.99	0.314	0.149	0.463	11.90	0.630	0.475	556.39	12704.01	8692.44	223.42
78.79	4.56	1.060	45.45	0.384	0.244	0.628	9.72	0.680	0.593	588.48	18292.39	16460.87	305.80
79.80	5.22	1.088	40.06	0.406	0.153	0.559	13.10	0.480	0.514	475.93	20001.74	14295.95	349.56
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A28. Annual data for ME1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.12	0.820	75.36	0.348	0.000	0.348	6.89	0.590	0.424	781.85	3553.39	8227.31	199.91
77.78	3.80	0.973	73.12	0.326	0.175	0.501	8.16	0.630	0.515	930.19	6348.78	9033.31	223.88
78.79	4.58	1.039	45.52	0.483	0.121	0.604	9.41	0.650	0.581	1916.65	11192.77	16276.73	223.01
79.80	5.22	1.074	39.94	0.441	0.180	0.621	8.60	0.430	0.578	1117.32	10789.07	17405.32	256.65
80.81	4.09	0.863	75.68	.	.	.	.	.	.	.	.	.	.
81.82	4.27	0.943	72.27	.	.	.	.	.	.	.	.	.	.
82.83	5.76	1.281	35.20	.	.	.	.	.	.	.	.	.	
83.84	5.02	1.200	30.43	.	.	.	.	.	.	.	.	.	

Table A29. Annual data for PT1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	3.82	1.199	73.83	0.175	0.226	0.401	21.60	0.890	0.335	263.50	2096.74	3423.60	65.15
77.78	3.80	0.988	72.80	0.304	0.225	0.529	9.07	0.540	0.535	580.96	12186.71	4559.81	63.54
78.79	4.34	1.213	73.15	0.318	0.319	0.637	14.30	0.550	0.525	1051.90	4725.96	14263.26	68.56
79.80	5.16	1.117	70.63	0.240	0.400	0.640	12.70	0.470	0.573	664.66	6203.69	8997.12	66.29
80.81	4.03	1.199	73.83	0.246	0.339	0.585	10.90	0.414	0.488	337.22	4056.06	6873.89	62.67
81.82	4.17	0.988	72.79	0.254	0.183	0.437	26.40	0.635	0.442	134.04	4972.92	3814.82	27.13
82.83	5.58	1.213	73.17	0.270	0.338	0.608	12.70	0.314	0.501	90.98	3388.60	6136.83	63.58
83.84	4.67	0.917	70.65	0.252	0.288	0.540	18.00	0.542	0.589	598.31	5424.18	6450.51	107.35

Table A30. Annual data for TBAY1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.19	1.199	73.83	0.107	0.148	0.255	24.40	0.900	0.213	161.62	6697.27	3352.94	74.79
77.78	3.91	0.988	72.79	0.078	0.497	0.575	12.60	0.620	0.582	564.24	74768.08	8027.02	113.52
78.79	4.59	1.213	73.18	0.184	0.602	0.786	26.20	0.720	0.648	1021.03	10722.99	13547.70	123.91
79.80	5.27	1.117	70.65	0.127	0.717	0.844	28.70	0.470	0.755	600.37	9795.39	15048.46	201.01
80.81	.	.	.	.	.	.	.	.	.	.	.	.	.
81.82	.	.	.	.	.	.	.	.	.	.	.	.	.
82.83	.	.	.	.	.	.	.	.	.	.	.	.	.
83.84	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A31. Annual data for TWN1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.19	0.837	75.67	.	.	.	.	.	.	.	.	.	.
77.78	3.91	0.987	73.52	0.412	0.087	0.499	8.09	0.510	0.505	2553.18	3281.01	9915.43	215.42
78.79	4.58	1.007	46.30	0.377	0.192	0.569	11.30	0.620	0.565	2153.89	3611.41	17641.84	245.66
79.80	5.27	1.087	40.13	0.385	0.236	0.621	9.54	0.430	0.571	2278.24	4747.77	19762.50	339.16
80.81	4.03	1.199	73.83	0.432	0.204	0.636	7.83	0.428	0.531	2482.49	4559.17	17801.66	306.02
81.82	4.17	0.988	72.79	0.425	0.055	0.480	14.30	0.514	0.486	2278.76	5354.29	12415.62	215.52
82.83	5.58	1.213	72.99	0.390	0.356	0.746	8.81	0.253	0.615	816.12	2740.23	17588.81	348.33
83.84	4.64	1.061	70.47	0.405	0.002	0.407	7.06	0.590	0.384	960.40	2524.25	9432.06	182.91

Table A32. Annual data for TWS1 catchment.

YEAR	TEMP	PRECIP	HUMID	BASE	QUICK	RUNOFF	MAXM	SPRING	YIELD	NH4	NO3	TON	TP
76.77	4.19	0.836	75.67	.	.	.	.	.	.	.	.	.	.
77.78	3.91	0.988	73.53	0.428	0.004	0.432	5.09	0.450	0.437	3952.56	2501.76	9219.91	204.69
78.79	4.58	1.007	46.40	0.326	0.240	0.566	11.30	0.660	0.562	4443.91	3375.28	16456.53	243.56
79.80	5.27	1.087	40.22	0.421	0.108	0.529	8.49	0.430	0.487	3167.90	2742.05	17851.29	270.32
80.81	4.03	1.199	73.83	0.419	0.225	0.644	8.01	0.422	0.537	1974.92	2613.43	18788.21	274.17
81.82	4.17	0.988	72.79	0.420	0.051	0.471	16.30	0.583	0.477	4155.73	3951.93	13328.64	331.77
82.83	5.58	1.213	72.99	0.370	0.342	0.712	9.90	0.249	0.587	1373.04	1752.17	17712.11	308.12
83.84	4.64	1.061	70.47	0.416	0.000	0.416	8.27	0.607	0.392	2632.97	2221.87	10724.31	235.35